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Lecture Number Six

"STATIC ELECTRICITY AND LIGHTNING HAZARDS"

Part II

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1.0 SQUIB AND DETONATOR SENSITIVITY

The voltages required to cause detonators and squibs to fire are very small. Most of those used at Cape Kennedy meet the "1 amp no-fire" specification and their resistances range from 0.04 to 1.0 ohm. This means that 1 ampere is exceeded when 0.04 to 1.0 volts are applied to these respective resistors.

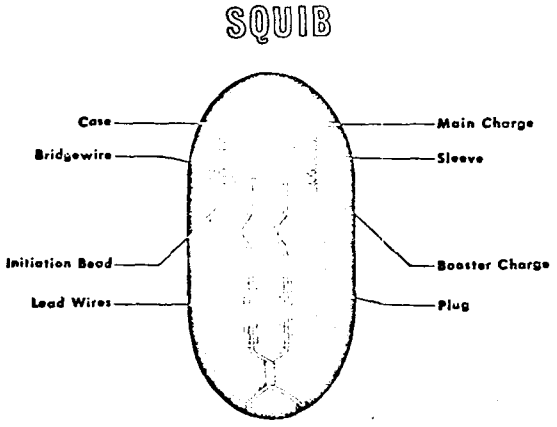

Figure 6-4

The amount of energy required to initiate either a squib or a detonator is very small when it is applied as a sharp spike. Exaggerated energy levels of 400,000 ergs magnitude are sometimes quoted, when this figure may actually be referring to a type of static electricity test in which a 5000 ohm resistor is in series. In this case nearly all of the energy goes into the series resistor. Values of 200 to 20,000 ergs are in the correct range, with the lower figure being more typical of detonators and the higher more typical of squibs. Unless reliable data is available proving higher values, 200 ergs should be used. Such values can be obtained, using square wave generators combined with a carefully set-up high speed oscilloscopic recording. Many initiators also exhibit greater sensitivity is being measured, rather than the sensitivity due to bridge wire heating.

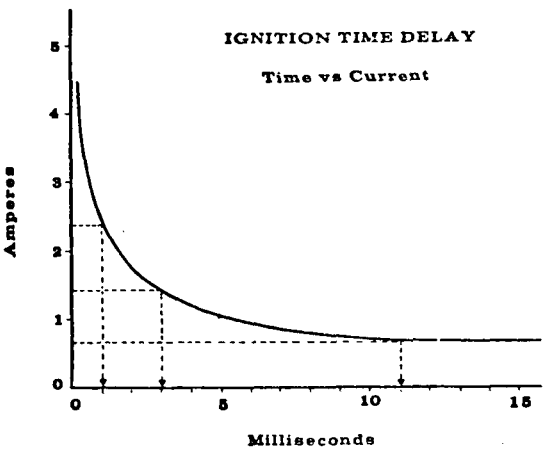

Figure 6-5

Do not make the mistake of figuring minimum initiating energies from minimum firing currents! The exact opposite condition is more nearly applicable. Minimum energy is required when very little of the energy is conducted from the wire and thus most of it is effective in heating the wire. This only occurs under very high rates of energy application in which initiation occurs in less than one millisecond.

For static electricity and lightning, the minimum initiating energy is generally the principle sensitivity yardstick. This may also be a good index for RF sensitivity, particularly for pulsed RF. The minimum voltage required for initiation is often the controlling sensitivity index for stray currents and sometimes for RF.

2.0 STATIC ELECTRICITY

Accidental initiation of squibs and detonators and of vapors and dusts by static electricity is considerably more frequent than is generally recognized. Fatal accidents are generally well publicized. Where injury is slight or nonexistent, very little publicity results.

The most positive protection of ordnance against static electricity is to have the detonator in a safe-and-arm device. This should not only protect the sensitive element, but also prevent propagation of ignition or detonation and be

self-contained in case the squib or detonator alone is somehow set off. This is definitely the preferred method of protection.

When squibs or detonators are not protected with safe-and-arm devices, they should at least be electrically shielded and the firing leads should be connected to that shield through a resistor of the order of a few hundred thousand ohms resistance. These should be present when shipped. This will give considerable protection. Any operations involving these devices should be done in a thoroughly grounded environment, including nearby personnel. Details of such grounding will normally be covered in SOP's. This grounding is somewhat more complex than might be immediately apparent, though it is simple in principle. Late-in-countdown installation of such unprotected devices is often requisite. Weight penalties from this can often counterbalance any savings in weight obtained by not using safe-and-arm device protection.

Insofar as possible, static accumulating materials should be kept away from unprotected squibs and detonators. Nonconductors are in general suspect, particularly many of the common packaging plastics. There are conducting plastics available to cover many applications. Any static accumulators used around unprotected squibs, detonators, explosive vapors or dusts are difficult to justify and should be specifically provided for if unavoidably present.

There are various survey meters which can detect the accumulation of static electricity. Their use, along with several "wiping cloths" for generating charges, can be quite helpful in assessing the static electricity hazards of an area. Nonconductors do vary greatly in their ability to act as static accumulators.

In considering static electricity, the following three functions require attention:

- Generation - Some type of friction or flow is generally involved. This may be a person's clothing or shoes brushing against an object, the flowing of a liquid, the flow of particles, the flow of suspended particles (dust, mists, rain), the action of machinery, the mixing or agitation of solvents, or other type motion process. Motion is a part of life and work, but careful grounding and selection of contacting material (cotton is better than most synthetic clothing) can help reduce generation.

- Accumulation - The positive or negative charges generated must be accumulated if a voltage is to be built up. Thorough grounding prevents this. Nonconductors are hard to ground, but may be discharged by wiping with a grounded conductor.

- Discharge - To cause a problem an accumulated charge must discharge. If sensitive elements such as squibs, detonators, vapors, or dusts are protected so that they are not part of the discharge path, then no problem will result. If intentional discharge is provided for, then a problem can be prevented.

3.0 LIGHTNING

More deaths are caused by lightning in the United States during an average year than by tornadoes or hurricanes. According to the National Bureau of Vital Statistics, an average of 230 persons a year were killed by lightning from 1946 to 1955. In Florida, 8.8 deaths per year occur (based on 1955 through 1964, inclusive). The figure has been lower in more recent years (possibly due to the increasing urbanization). On the basis of population, it appears that a person in the United States currently has about a one-in-a-million yearly chance of being struck by lightning. This does not give a true picture of the odds because rural areas have more fatal strikes and fewer people than urban areas. It has been estimated that 90 percent of the cases in which persons were fatally struck by lightning occurred in rural areas. That's not the whole story either. According to the Lightning Protection Institute, lightning kills more than 600 persons annually if persons who die in fires caused by lightning are included. An additional 1,500 more are injured and property damage amounting to $120 million is done. Where you are and what you do, during a lightning storm, can make your chances uncomfortably good for being in or near a lightning strike.

LIGHTNING SAFETY

Safe Locations

- Within building with lightning protection
- Inside steel-topped automobile

Unsafe Locations

- Under tall tree
- Water shore
- Walking highway
- Atop building
- Open field
- Open water
- Mountain top

Figure 6-6

There is much misunderstanding and lack of knowledge about how lightning occurs and what a person should do during a storm. Standing under a tree, particularly if it is isolated and tall, is one of the best ways to be killed by lightning (whether you are touching the tree or not). Standing in the water is inviting trouble in two ways: by direct stroke because you are the highest point on a flat surface, or through the water from a nearby strike.

Actually, a steel-topped car is one of the safest places during a lightning storm. No instance of a fatality in a car from a strike has even been recorded.

One of the worst problems about lightning is that people underestimate it. How many times a year would you figure that lightning strikes the land area of the United States? If you guessed 29.5 million times you're right (8 strikes per square mile). Each day, throughout the world, an average of 44,000 thunderstorms produce about 100 lightning strokes per second. According to Peter E. Viemeister, in his excellent work on this subject, The Lightning Book, an average 30,000-ampere stroke under 125 million volts may develop 3,750 million kilowatts. This is more than the total capacity of all the power plants in the United States. But because the duration is short, only about 250 kilowatt-hours are used, worth about $7.50.

The U. S. Weather Bureau has compiled an isokeraunic map of the United States, by which it is possible to estimate the average number of thunderstorm days per year for any area. Central Florida is tops for the United States with up to 100 days each year. By contrast, the West Coast has fewer than five days per year. (The number of storms per year is 140/5 for Central Florida/West Coast.)

Some spots receive far more than their fair share of lightning strikes. High points, reaching up from the ground above other nearby objects on the earth's surface, take the brunt of lightning attacks. Tall trees, mountaintops, flagpoles, church spires, barns, and tall buildings are among the leaders.

The Empire State Building took sixty-eight strokes in three years. This dispels the idea that lightning never strikes twice in the same place. The fact is--and it is worth remembering--that lightning more than likely will strike the same place twice if it doesn't destroy the thing it hit the first time. It's true there are many random strikes that are never repeated, but choice spots,

whether because they are tall or located in areas with a good conductive ground, are hit repeatedly. This explains why rural areas have most lightning fatalities. Tall buildings in cities take the strikes at their tops and conduct the electricity safely into the ground.

One curiosity of lightning fatalities is that five times as many men are killed as women. This undoubtedly reflects the fact that more men than women are outdoors at any given time, and thus have more exposure, but it also mirrors a difference in attitude about lightning. Men tend to ignore lightning and go right on doing whatever they are at; women, on the other hand, take no shame in being afraid of it, and head for the best protection they can find.

It is possible to be just plain unlucky, as the tragic case of an Illinois farmer illustrates. The Weather Bureau reports that the man's barn was set afire by lightning and the conflagration killed all his livestock except two horses. A week later lightning struck again, destroying his metal hay shed; then a few days later it flicked along a fence and knocked the farmer unconscious. A month after that he was standing in a neighbor's barn when lightning struck him in the chest and killed him but damaged nothing else.

Lightning may be separated into four broad classes:

- Cloud-to-Ground and Ground-to-Cloud - Generally jumps from cloud to ground with return stroke from ground to cloud. When building heights exceed 200 feet, there is a significant probability of earth to cloud strokes. For the Empire State Building (1250 feet height) eighty percent are of the latter type.
- Cloud - includes intracloud, intercloud, and cloud to air.
- Tornado type - interior of tornado is typically an area of continuous and high intensity electrical discharge.
- Ball or Bead.

Only the first and third types will be discussed, but cloud types may sometimes cause trouble due to induced ground voltages. Cloud-to-ground lightning is essentially a transient DC discharge. It is characterized by a rise time of the order of a few microseconds and a general irregular decay over a period of perhaps 0.25 seconds. Test records have indicated that:

- Seventy percent of the strokes have a peak potential of over 2,000,000 volts.
- The maximum peak potential sometimes exceeds 20,000,000 volts.
- Peak currents of 50 percent of the strokes will exceed 13,000 amperes.
- Peak currents of 10 percent of the stroke will exceed 32,000 amperes and maximum currents may exceed 160,000 amperes.
- Most lightning initiates as a shift of electrons from a cloud to earth.

Direct impact of a lightning strike on a solid propellant rocket or explosive device would have an excellent probability of starting a serious fire at the impact point. Except for the impact point, heating by conduction through a metal case would often not cause a problem, but should be studied on an individual case basis. The possibility of inducing dangerous voltages into a squib or detonator is significantly high when the squib or detonator is not in a safe-and-arm device. Great care must be taken to protect such squibs and detonators, particularly when they are installed in motors or firing trains. Buildings containing such devices might well be equipped with a separate elevated "cone of protection" type of lightning protection, as well as being proviced with good building structural grounding.

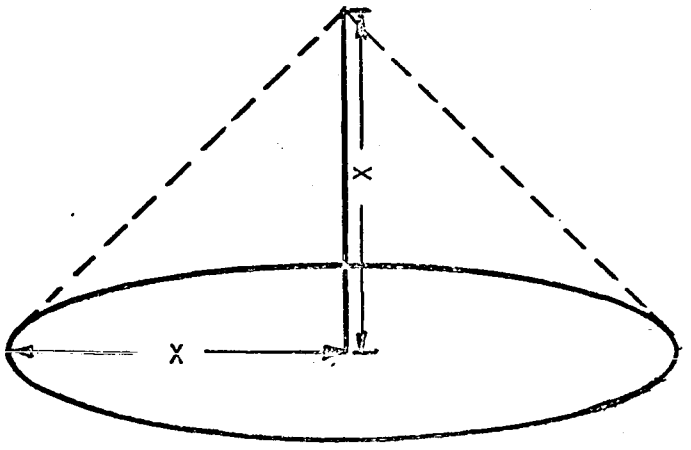

Figure 6-7. CONE OF PROTECTION

Lightning protection can be most simply considered from the zone of protection approach. A well grounded, pointed, upright conductor will protect the zone included by a cone terminating at its point and with a base equal in radius to

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Where tall steel towers and steel-framed buildings exist at Cape Kennedy, they give excellent protection from direct lightning strikes, provided they are well grounded. They will also probably be struck fairly frequently. There must thus be careful attention given to the protection of ordnance devices which might create a hazard, should they be initiated by induced currents or by currents resulting from arc-over.

Careful studies of tornadoes have shown that they are very intense electrical storms as well as windstorms. This electrical activity appears to be of a continuous type (more like a massive corona discharge). Since tornadoes are frequent in this area, this electrical characteristic should be kept in mind when assessing their possible damage to a rocket or ordnance facility.

The onset of lightning at a particular place can be predicted with considerable success while storms are still some distance away. These devices generally use field strength measurements plus counting and measuring of the electromagnetic fields resulting from lightning discharges. They can be of considerable assistance in planning operations on an hourly basis.

4.0 CONCLUSIONS

Static electricity and lightning have a significant probability of initiating squibs or detonators and damaging electronic equipment unless they are protected by safe-and-arm devices or by careful grounding plus other protective techniques. These are also quite dangerous with respect to initiating fires or explosions in the vapors and dusts which occur during many operations, such as handling liquid propellants and solvents.

(This lecture was accompanied by a film which is highly recommended to the reader; "Static Electricity", obtainable from the American Gas Association, Inc., New York, New York.)

its height. A number of points which are vertically connected to the ground, and also horizontally connected near their points, will give a tent-like zone of protection.

A steel frame building will give excellent protection, provided it is well grounded and has lightning rods installed.

The above types of protection do not give complete protection from induced voltages and secondary arcs. The very high peak currents mentioned above are accompanied by intense electromagnetic fields which can induce significant voltages in nearby lines. In addition, a few ohms resistance to ground will, (by direct IR drop), permit large voltages to build up with possible arc-over to nearby conductors.

When the need for secondary protection exists, double-layer protection can be of great help. A well-grounded, steel-frame building may be one layer. A separate lightning-rod system of aerial protection may be used for the other layer. Particularly sensitive devices might be screened by copper screening if very high protection from the electromagnetic field is desired.

Pointed lightning rods do serve to reduce the electrical potential by early discharge, as well as act as a preferred path.

Ungrounded objects such as tall trees are poor conductors and are thus not protectors, although they are sufficiently preferred paths to act as a focus for lightning discharge. When lightning strikes trees it may jump to a nearby object. It also tends to spread out about the base of the tree. If the ground is dry, a person or animal may be connected through his feet. Five hundred and three sheep were killed in this manner by a single lightning stroke. In some cases it would seem worthwhile to run a well grounded lightning rod up a tree, thus changing a hazard into a protective shelter.

Much of this discussion has been about people. Wherever there is a hazard to people, there is a hazard to unprotected ordnance devices and electronic equipment. In fact, particularly with respect to induced voltages, the ordnance devices and electronic equipment may be considerably more sensitive than a person.